Abstract Presentation Back to Agenda Next Abstract

A Java-based Web Interface to Matlab

Siddharth Samsi, Ashok Krishnamurthy and Stanley Ahalt
The Ohio State University

Matlab, from The Mathworks Inc., is a technical computing environment that is widely used in the scientific and engineering communities for research and development. The basic product can be augmented by a variety of toolboxes that extend it's capabilities in specialized areas such as Signal and Image processing, Control System Design, Financial Analysis, etc. There are many situations in which it is desirable to access MATLAB and toolbox functionality over the World Wide Web. For example, a research group may want to allow other researchers to test and benchmark their MATLAB code using data available over the web. The Matlab Web Server, also available from MathWorks Inc., makes it possible to deploy Matlab applications over the internet. However, the Matlab Web Server does not preserve the user workspace, making it difficult to create applications that make the online Matlab experience as rich as a locally run Matlab session.

This paper discusses the development of an alternative method for deploying Matlab applications over the Web. The system developed here aims at overcoming many of the limitations of the Matlab Web Server, resulting in a more interactive online Matlab experience. Using the MATLAB-Java interface available in the recent releases of MATLAB, our system provides the web interface through the use of Java Servlets and custom Java classes. As shown in Fig. 1, a multithreaded socket is used to start a new Matlab process for every user that logs into the system. Once the Matlab process for a user has been started, all communication between the user and Matlab process is facilitated by the servlet and the Java socket opened by Matlab. This allows each user to have a workspace that is preserved until his/her Matlab process exits. This also has the advantage that no additional server-side programming is needed specifically to save user data and have a unique identifier to associate it with the user.

We will show an example of a web-accessed MATLAB application that allows a user to access acoustic signals stored in a mySQL database, search for signals that meet a user-selected criterion, analyse the selected signal using a variety of signal processing algorithms and create 2-d and 3-d plots of the signal and analysis results. The user also has the ability to playback and listen to selected portions of the signal. The preservation of the user workspace means that the user can zoom in and examine portions of the signals in more detail without having to rerun the analysis each time. The zooming and playback of the signals is accomplished using Java applets that are downloaded to the user's browser. This example

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **20 AUG 2004**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **A Java based web interface to Matlab**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **The Ohio State University Columbus, OH 43210**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM001694, HPEC-6-Vol 1 ESC-TR-2003-081; High Performance Embedded Computing (HPEC) Workshop (7th)., The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**45**	

Abstract
Presentation
Back to Agenda
Next Abstract

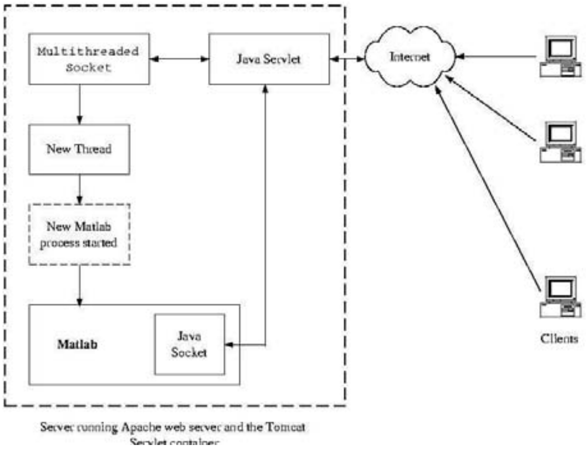

Multithreaded Socket
Java Servlet
Internet
New Thread
New Matlab process started
Matlab
Java Socket
Clients
Server running Apache web server and the Tomcat Servlet container

Figure 1: System overview

system also shows how to use Java Database Connectivity (JDBC) to access and manipulate the signal database.

An important application of such a system is a research oriented web portal where a community of scientists and researchers can share data and code with each other. The portal can allow authenticated users to download MATLAB code which is then immediately available to other users to test and examine results. Any specialized toolboxes required need be hosted only on the server system running MATLAB and need not be replicated at each user site.

This work was supported in part by the DoD High Performance Computing Modernization Program's PET program.

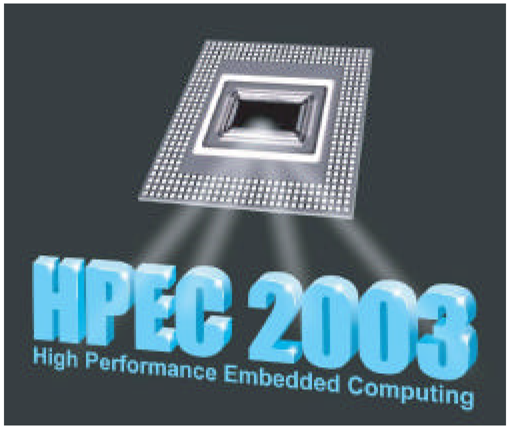
References

1. J. Hunter and W. Crawford, *Java Servlet Programming*, O'Reilly & Associates, 2 ed., 2001
2. D. R. Callaway and D. Coward, *Inside Servlets: Server-Side Programming for the Java(TM) Platform*, Addison-Wesley Pub. Co., 2nd ed., 2001
3. W. R. Stevens, *UNIX Network Programming*, Prentice Hall PTR, 2 ed., 1998
4. MATLAB and MATLAB Web Server documentation from MathWotks, Inc., *http://www.mathworks.com*
5. Sun Microsystems, *http://java.sun.com*
6. The Apache Software Foundation, *http://www.apache.org*
7. The Jakarta Project, *http://jakarta.apache.org*

Abstract Presentation

Back to Agenda

Next Abstract



A Java based web interface to Matlab

Siddharth Samsi, Ashok Krishnamurthy,
Stanley Ahalt, John Nehrbass, Marlon Pierce

Outline

- Motivation and Goals
- Matlab Web Server from MathWorks
- The OSU Matlab Application Portal
- Steps for creating a typical portal application
- An example Matlab application using the portal
- Advantages and Limitations
- Future work

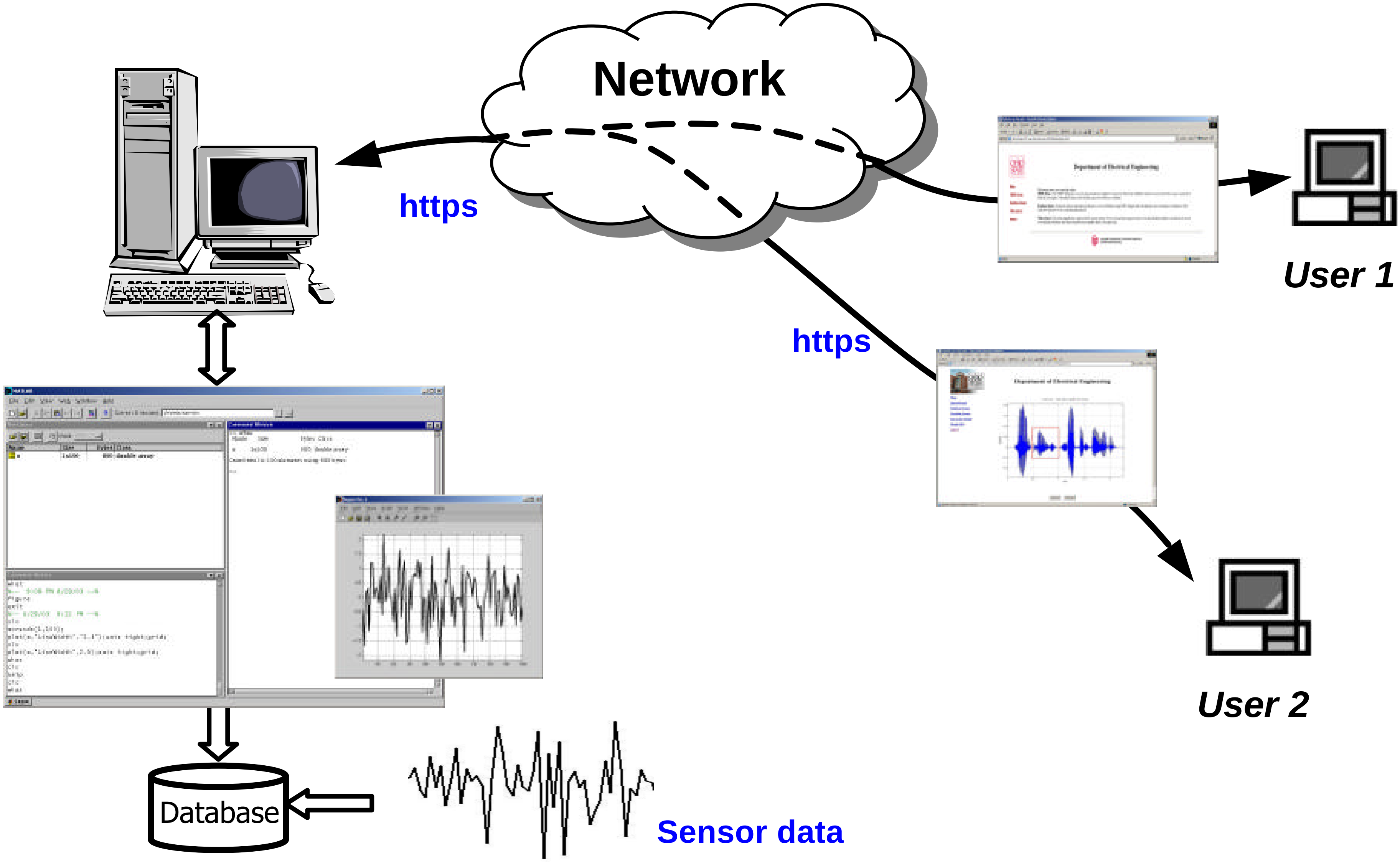
Motivations

- Matlab is a widely used computational environment for research and development
- Many large applications continue to be developed and deployed using Matlab
- Researchers from geographically distributed locations want to share applications and data
- Users want to run Matlab applications without having to buy licenses for all toolboxes
- Solution: A secure, web based Matlab application portal that allows researchers to upload code, run applications and visualize results

Goals

- Create a portal capable of running Matlab applications over the web
- Provide the ability to interactively zoom and examine 2-D and 3-D plots
- Provide the ability to upload Matlab code for testing and benchmarking on common data
- Provide secure access to the Matlab application portal through user authentication and encrypted communication

Goal

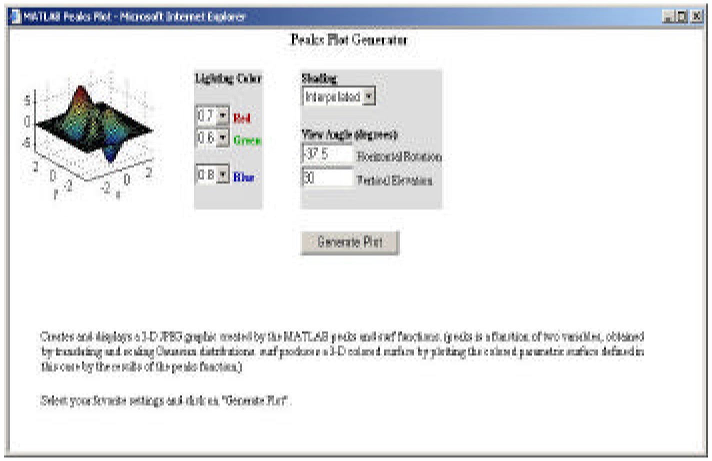


Benefits of Research Portal

- Provides common platform for sharing data
- Enables easier sharing of code and results with the entire research community
- Single web based environment can provide easy access to all analysis tools
- Web interface can also be used to perform batch processing tasks more easily

Matlab Web Server

- Interface between the web and Matlab
- Uses Common Gateway Interface (CGI) to provide web based communication
- Provides helper functions for creating output HTML from result data
- Enables any Matlab application to be accessed over the web



MATLAB Peaks Plot - Microsoft Internet Explorer

Peaks Plot Generator

Lighting Color

0.7 Red

0.6 Green

0.8 Blue

Shading: Interpolated

View Angle (degrees)

-37.5 Horizontal Rotation

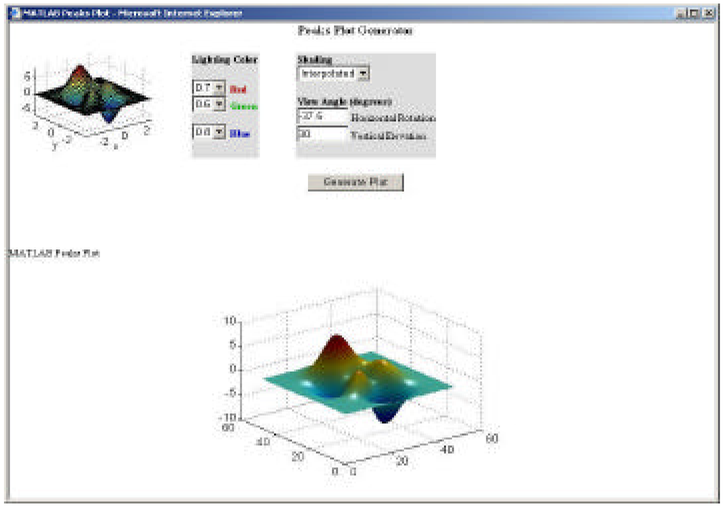
30 Vertical Elevation

Generate Plot

Creates and displays a 3-D JPEG graphic created by the MATLAB peaks and surf functions. (peaks is a function of two variables, obtained by translating and scaling Gaussian distributions. surf produces a 3-D colored surface by plotting the colored parametric surface defined in this case by the results of the peaks function.)

Select your favorite settings and click on "Generate Plot".

Input Page



MATLAB Peaks Plot - Microsoft Internet Explorer

Peaks Plot Generator

Lighting Color

0.7 Red

0.6 Green

0.8 Blue

Shading: Interpolated

View Angle (degrees)

-37.5 Horizontal Rotation

30 Vertical Elevation

Generate Plot

MATLAB Peaks Plot

Results

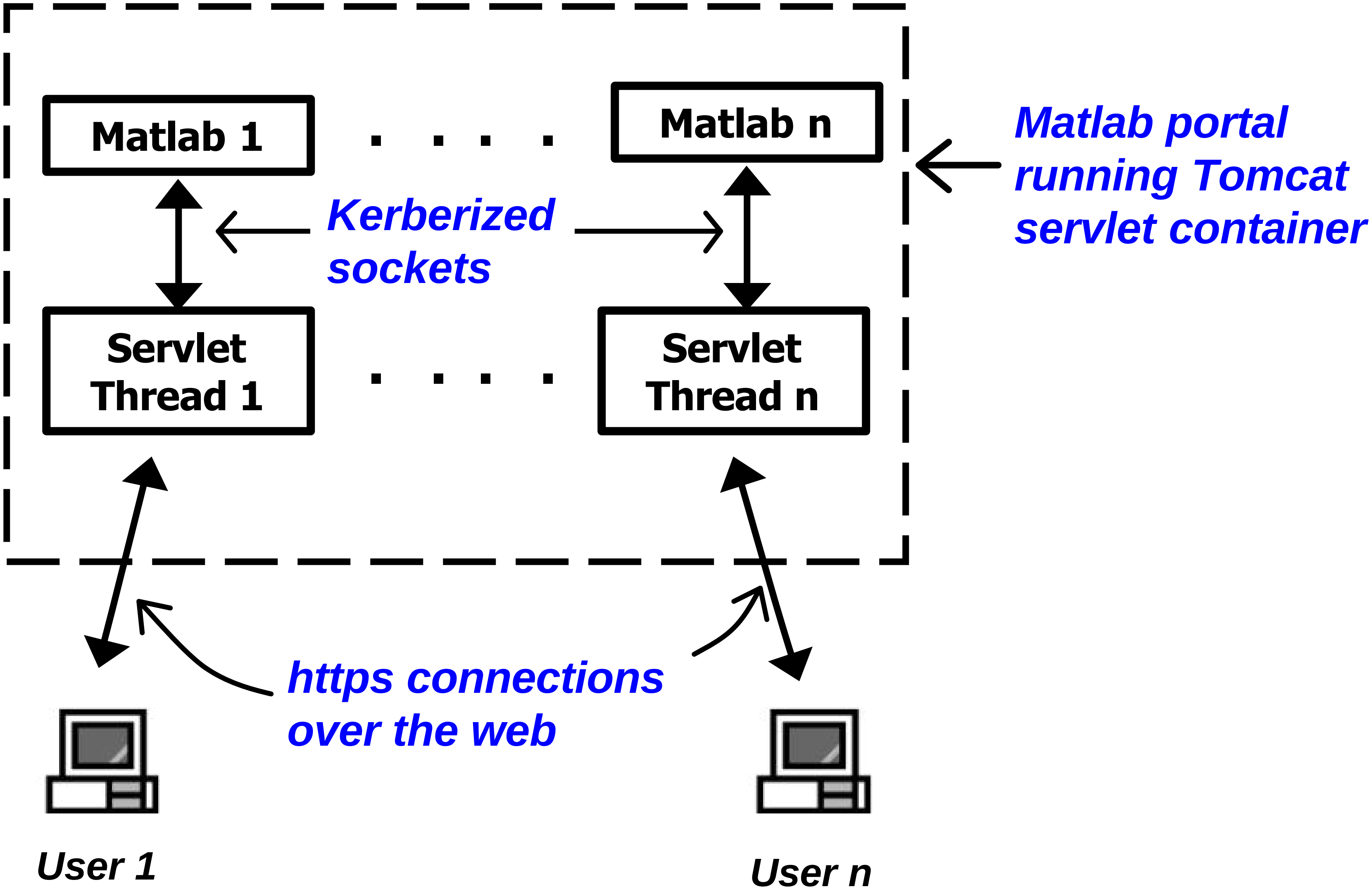
Limitations of Matlab Web Server

- Matlab workspace is not retained
  - All variables and data generated by an application is lost upon completion of the program
  - Results need to be recomputed for subsequent analysis by other applications
- Does not provide interactivity with Matlab graphical output
- Difficult to track users
  - The system does not have a concept of sessions
- Does not provide network security
  - No data encryption provided
  - User authentication not provided

The OSU Matlab Portal

- Based on standard open source industry components: Apache, Tomcat, Linux, MySQL
- Java technology used to build a web interface to Matlab
  - Matlab includes a Java Virtual Machine (JVM), providing access to Java objects
- Java servlets enable web based communication
- Kerberized Java sockets facilitate communication between Matlab an servlet
- Secure socket layer (SSL) used for encryption of all communication over the web

System Overview



Java Servlets

- Java servlets perform the following functions
  - Authenticate users
  - Start a new Matlab process for each new user
  - Communicate with user's browser using the https protocol
  - Communicate with user's Matlab process using kerberized sockets
  - Track users through sessions

Kerberos, Java Sockets and Servlet

- The Kerberos mechanism is used for secure message exchanges using sockets
- The OSU Matlab portal uses Kerberos V5 mechanism for secure communication
- Kerberos ticket required for establishing credentials and secure communication
- Kerberos tickets expire when user logs out of the portal

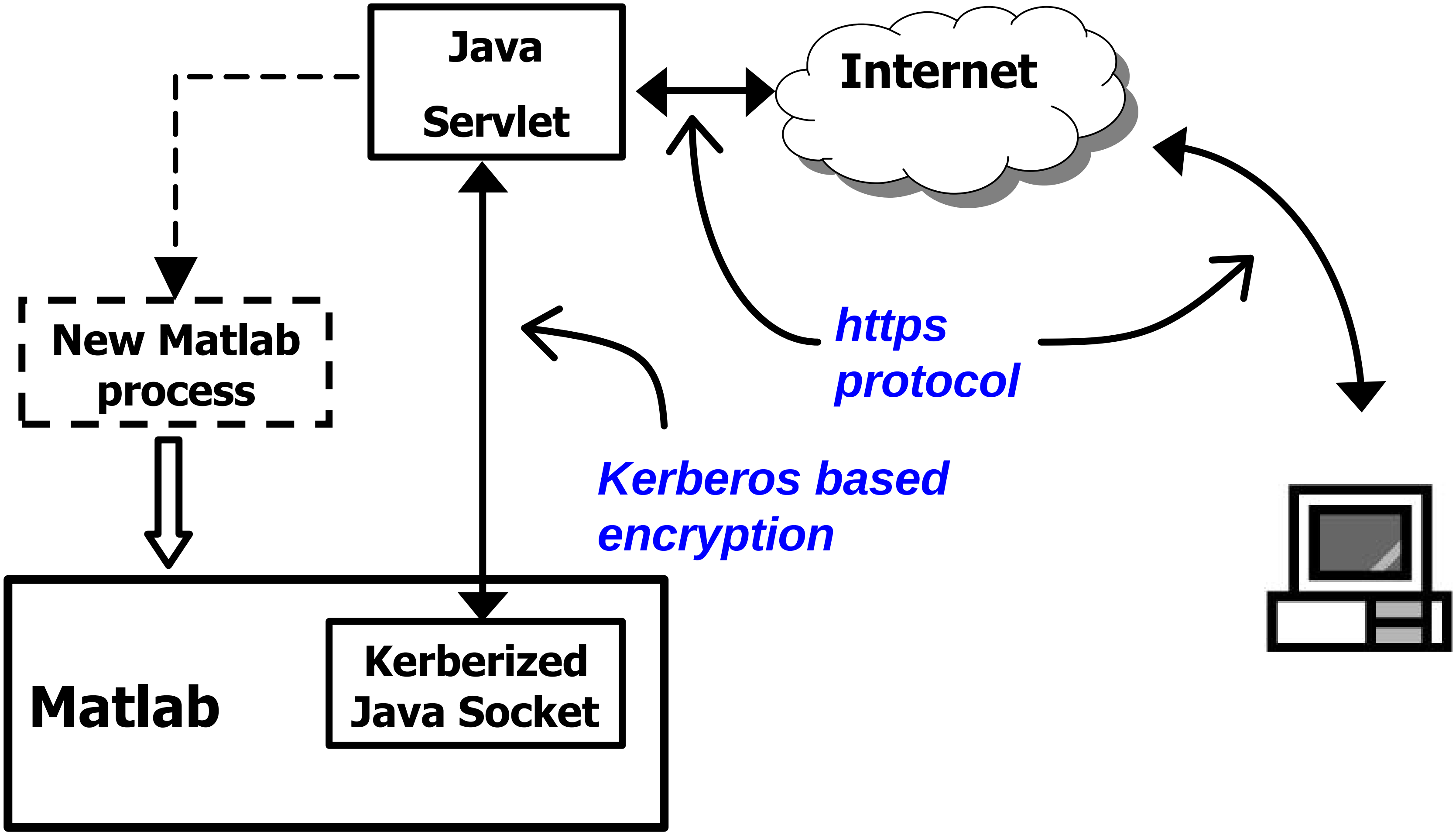
Kerberos based communication

- Once a user is authenticated and logged in, a unique Kerberos ticket is generated
- Communication process:
  - Connection is established between Java socket and Servlet
  - Socket and Servlet instantiate a new security context for communication
  - Using the Kerberos ticket the Socket and Servlet mutually authenticate and exchange tokens for encryption
  - All communication between them is now encrypted using previously exchanged tokens

Database Access using JDBC

- Matlab provides the ability to access Java objects
- Custom Java classes and Java Database Connectivity (JDBC) are used to accesses databases
- Matlab can extract data from JDBC compliant databases using these classes
- Provides independence from the Matlab Database Toolbox

User Login Process



https protocol

Kerberos based encryption

Designing Portal Applications

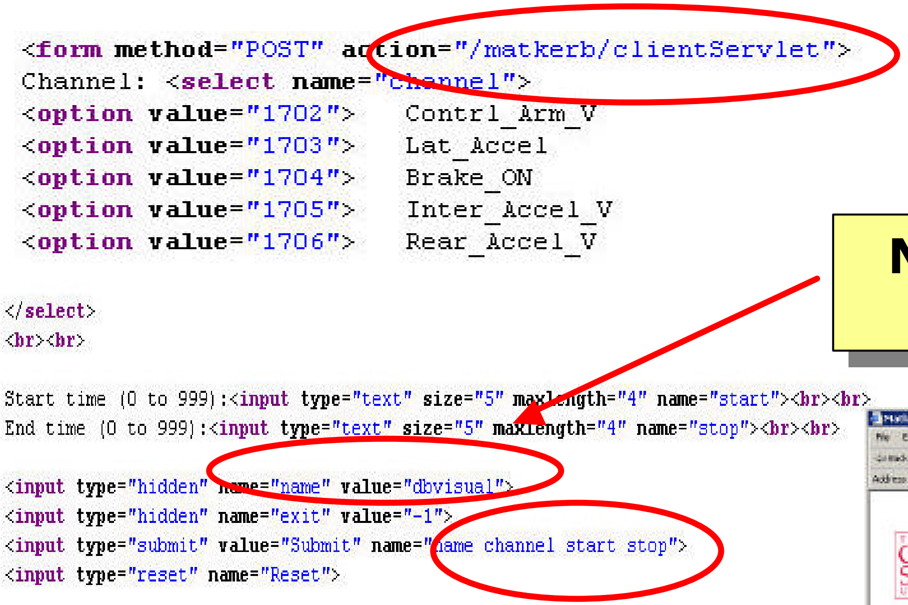
- Create necessary Matlab m-files
- Input to Matlab
  - Obtained from user, over the web
  - HTML forms can be used
- Output from Matlab
  - Results are displayed in the user’s browser
  - Necessary HTML can be created in Matlab as a string
  - Can use templates for generating output HTML
- Modification of configuration file
  - New applications should be registered with the server

Input from user to Matlab

- Input parameters to Matlab obtained from the web
- Standard HTML forms can be used to obtain user input
- HTML forms support input in the form of
  - Plain text
  - Pull down menus
  - Boolean operators (e.g.: HTML Radio buttons)

Sample Input HTML

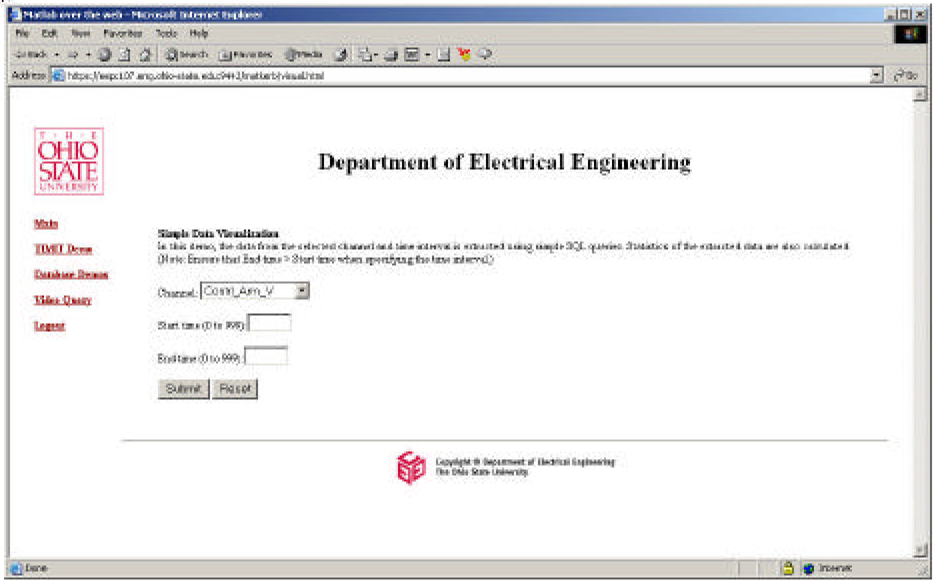
Call servlet to send request to Matlab



```
<form method="POST" action="/matkerb/clientServlet">
Channel: <select name="channel">
<option value="1702">   Contrl_Arm_V
<option value="1703">   Lat_Accel
<option value="1704">   Brake_ON
<option value="1705">   Inter_Accel_V
<option value="1706">   Rear_Accel_V

</select>
<br><br>

Start time (0 to 999):<input type="text" size="5" maxlength="4" name="start"><br><br>
End time (0 to 999):<input type="text" size="5" maxlength="4" name="stop"><br><br>

<input type="hidden" name="name" value="dbvisual">
<input type="hidden" name="exit" value="-1">
<input type="submit" value="Submit" name="name channel start stop">
<input type="reset" name="Reset">
```

Name of application m-file to run

List of parameters for the specified application m-file



Matlab over the web - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites Media
Address https://eepc107.eng.ohio-state.edu:9443/matkerb/visual.html
Go
THE OHIO STATE UNIVERSITY
Main
TIMIT Demo
Database Demos
Video Query
Logout
Submit
Reset
Done
Internet

Department of Electrical Engineering

Simple Data Visualization
In this demo, the data from the selected channel and time interval is extracted using simple SQL queries. Statistics of the extracted data are also calculated.
(Note: Ensure that End time > Start time when specifying the time interval)

Channel: Contrl_Arm_V

Start time (0 to 999):

End time (0 to 999):

Copyright © Department of Electrical Engineering
The Ohio State University

Output from Matlab

- Results from Matlab are displayed in the user's browser
- Output HTML can be created as a Matlab string
  - Application m-file responsible for adding necessary HTML tags
  - Data from Matlab should be converted to appropriate form
- Use of HTML templates
  - Helper functions are provided to substitute the appropriate data into a template
  - Simpler to change the way results are displayed

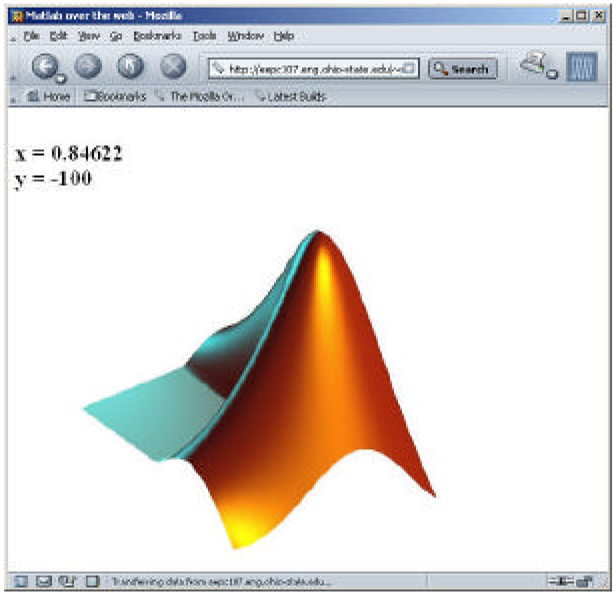
Sample Output HTML using templates

```
<html><head><title>Matlab over the web</title>
</head><body>
<br>x = #x#
<br>y = #y# <br>
<image src=“#image1#">
</body></html>
```

The‘#’ sign is used to enclose the output variables in HTML template

- Use Matlab function *gethtml,* for creating the output HTML :
  html = gethtml (‘template.html’, ‘x’, randn(1), ‘y’, -100, ’image1’, ’logo.jpg’);

```
<html><head><title>Matlab over the web</title>
</head><body>
<br>x = 0.84622
<br>y = -100 <br>
<image src="http://eepc107.eng.ohio-state.edu/logo.jpg">
</body></html>
```


Matlab over the web - Mozilla
File Edit View Go Bookmarks Tools Window Help
http://eepc107.eng.ohio-state.edu/~
Search
Home Bookmarks The Mozilla Or... Latest Builds
Transferring data from eepc107.eng.ohio-state.edu...

```
x = 0.84622
y = -100
```

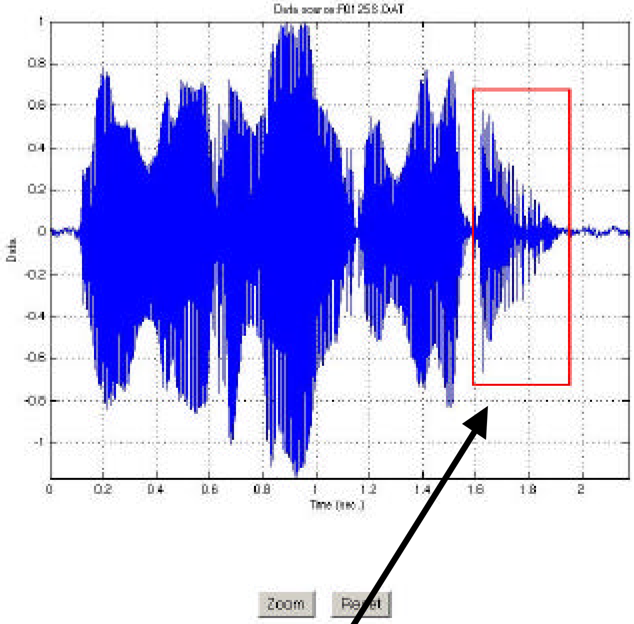
Interacting with Matlab graphics

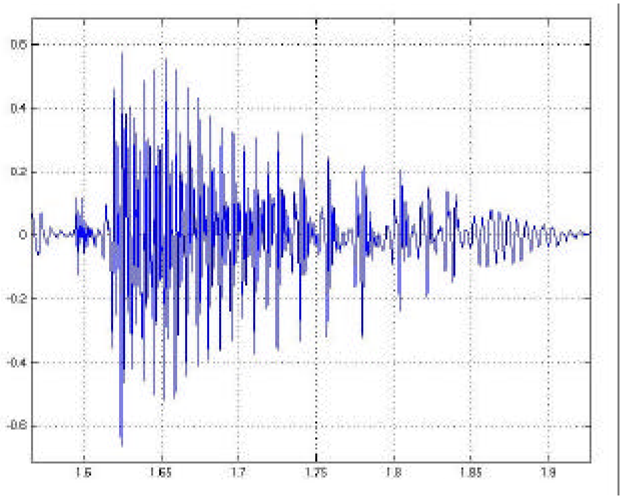
- Java Applets are provided to enable interaction with Matlab generated graphics
- Applets facilitate:
  - Displaying of images at desired location
  - Capturing mouse events and mouse pointer co-ordinates
  - Drawing lines and rectangles to show the “zoom area”
- Applets also give the ability to play .wav and .au files

Interacting with Matlab graphics

- JavaScript is used to access mouse co-ordinates from the Java Applet
- Used to set parameter values to be sent to Matlab
- JavaScript can also be used to generate web pages

Example of graphical interaction





- “Zoom” area drawn by Applet.
- Zoom co-ordinates are read using JavaScript and sent to Matlab

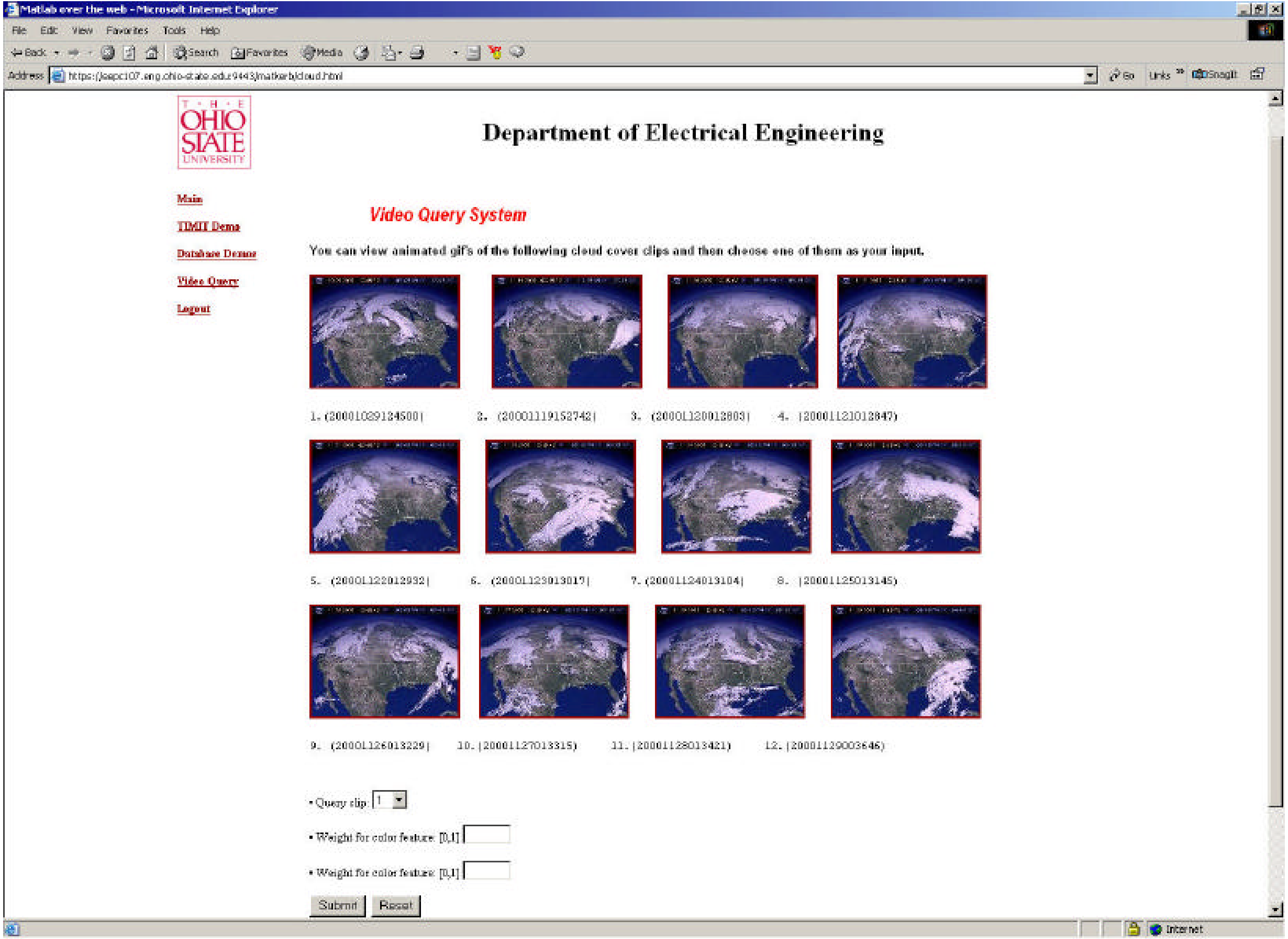
Result of zoom

- **Zooming achieved by replotting data with appropriate axes**

Sample Application

- Video Query System:
  - User selects an input cloud cover image
  - Available cloud cover images are in the form of animated gifs
  - User chooses the weights to be assigned to the color feature and the motion feature
  - Based on user input, Matlab returns the images most similar to the test image

Video Query: Input HTML page


Matlab over the web - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites Media
Address https://eepc107.eng.ohio-state.edu:9443/matkerb/cloud.html
Go Links SnagIt
THE OHIO STATE UNIVERSITY
Internet

Department of Electrical Engineering

Main

TIMIT Demo

Database Demos

Video Query

Logout

Video Query System

You can view animated gif's of the following cloud cover clips and then choose one of them as your input.

1. (20001029124500) 2. (20001119152742) 3. (20001120012803) 4. (20001121012847)

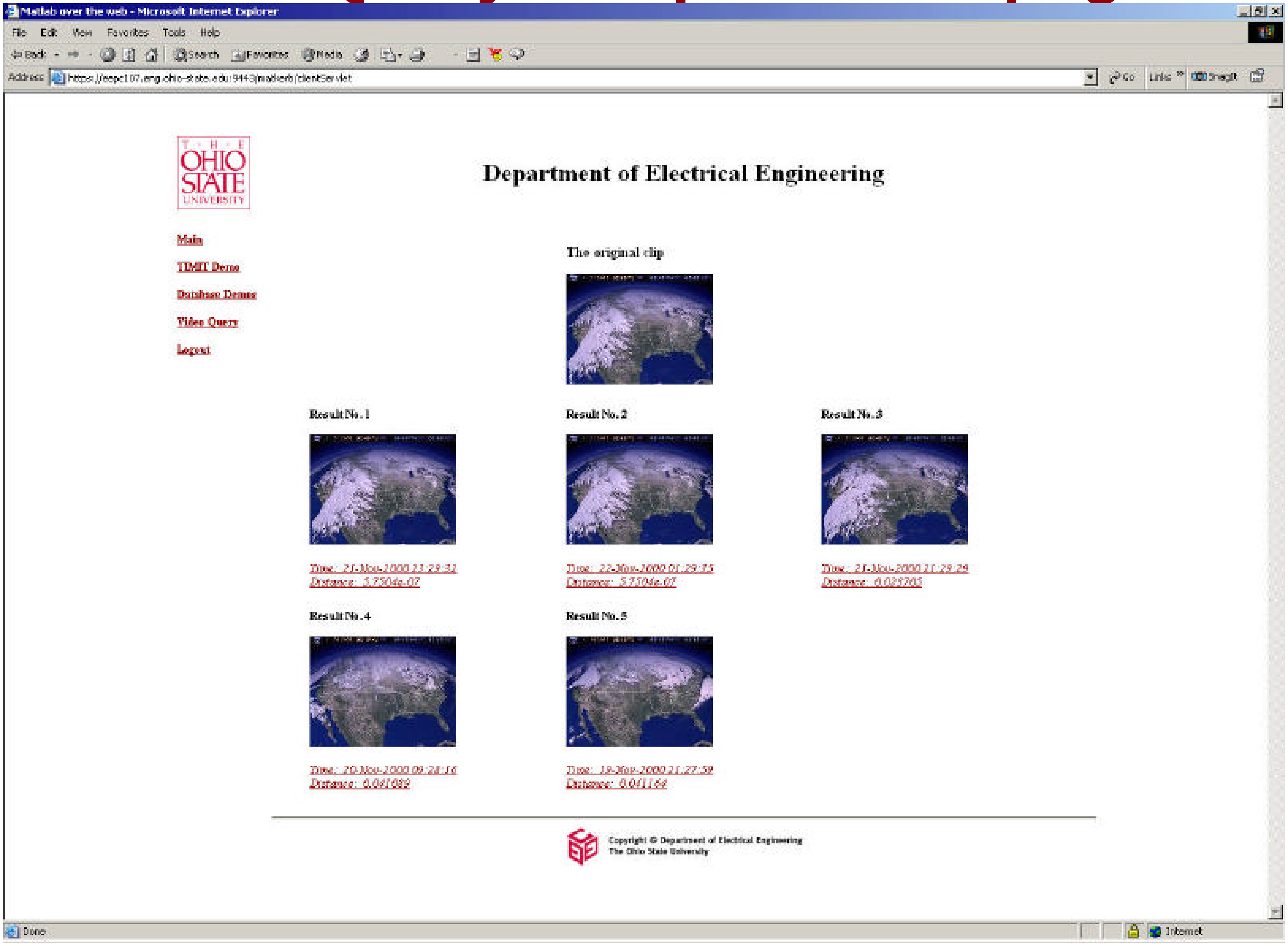
5. (20001122012932) 6. (20001123013017) 7. (20001124013104) 8. (20001125013145)

9. (20001126013229) 10. (20001127013315) 11. (20001128013421) 12. (20001129003646)

- Query clip: 1
- Weight for color feature: [0,1]
- Weight for color feature: [0,1]

Submit Reset

Video Query: Output HTML page



Matlab over the web - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites Media
Address https://eepc107.eng.ohio-state.edu:9443/matlab/clientServlet
Go Links SnagIt
THE OHIO STATE UNIVERSITY

Department of Electrical Engineering

Main

TIMIT Demo

Database Demos

Video Query

Logout

The original clip

Result No. 1

Time: 21-Nov-2000 23:29:32
Distance: 5.7504e-07

Result No. 2

Time: 22-Nov-2000 01:29:35
Distance: 5.7504e-07

Result No. 3

Time: 21-Nov-2000 21:29:29
Distance: 0.029705

Result No. 4

Time: 20-Nov-2000 09:28:16
Distance: 0.041089

Result No. 5

Time: 19-Nov-2000 21:27:59
Distance: 0.041164

Copyright © Department of Electrical Engineering
The Ohio State University

Deploying OSU Matlab Portal

- Core OSU Matlab components
  - Java Servlets and classes
  - Matlab m-files
  - Basic HTML web pages
- Software and Libraries required
  - Virtual Network Computing (VNC): Needed for providing Matlab with a virtual X-display
  - Kerberos clients
  - Tomcat servlet container
  - Java SDK
  - Apache Ant: Needed for compilation of Java source
  - C compiler

Installing the OSU Matlab Portal

- Shell scripts are provided to aid the installation of the portal
- Shell script performs following functions:
  - Creating the necessary directory structure
  - Reading environment variables and modifying the Java source code accordingly
  - Compilation of all source code
  - All class files, Matlab m-files and configuration files are put into appropriate directories
  - Cleanup: Removal of intermediate files

Registering Portal Applications

- Any new Matlab application to deployed must be registered with the portal
- For this, a configuration file is provided: *deploy.xml*
- *deploy.xml* contains:
  - Application name
  - Input parameters expected and their names
  - Database to used, if needed
  - Application m – file name

Sample Configuration file *deploy.xml*

```
<?xml version="1.0"
   encoding="ISO-8859-1" ?>
<webapps>
<application>
<name> dbvisual </name> }
<num - args>2</num - args>
<args>
<param>channel</param>   }
<param>stop</param>
</args>
<db>
<name>atcdata </name> }
</db>
<mfile> dbvisual</mfile> }
</application>
</webapps>
```

Application name

List of input parameters

Database to be used

Application m-file

Limitations

- Matlab memory requirements
  - Each Matlab process uses 50 Mb RAM on startup
  - Memory used increases as more variables are created
- JavaScript and Applets needed for interacting with graphics
  - Disabling JavaScript removes all graphics interactivity
- Currently limited to Unix/Linux platforms

Future Work

- Provide ability to upload and download data as well as Matlab code
- Provide bulletin board for exchange of ideas, problem discussion, etc.
- Develop administrator tools for portal
  - Make provisions for adding/removing users
  - Tools for portal administration
- Provide comprehensive documentation for the portal

Conclusion

- The OSU Matlab Portal has more flexibility than the Matlab Web Server from MathWorks
- Possible to create more interactive applications, e.g: zooming into images
- Eliminates the need for each user to buy Matlab and all toolboxes
- Less expensive alternative since it is based on freely available software/libraries

Additional Slides

Matlab Display Issues

- When run as a background process, Matlab runs in the terminal emulation mode
- Problems:
  - No X-Display available for Matlab
  - Cannot produce JPEG images directly
  - Representation of result data severely limited
- Solution:
  - Use Virtual Network Computing (VNC)
  - Matlab uses this X display for generating graphics

Virtual Network Computing (VNC)

- Remote display system
- Used to create a virtual desktops
- This virtual desktop can be access from a variety of platforms (Unix/Linux, Windows, MacOS)
- Has very small memory requirements
- Web site:

  http://www.uk.research.att.com/vnc/

Input to Matlab from the Web

- All Matlab applications deployed through the portal get input parameters from the user over the web
- Names of parameters are specified in *deploy.xml*
- The parameters are returned in the form of a structure *paramStruct*
- All applications have access to this variable in the workspace
- Applications must convert parameters from a string to appropriate format

Example: Accessing input parameters

- **Consider an application with the following input parameters:**
  - ***channel* : string**
  - ***start_time*: integer**
  - ***stop_time*: integer**
- **User input over the web:**
  - ***channel='engine_speed'***
  - ***start_time=10***
  - ***stop_time=40***

Example (continued)

- In Matlab, the parameters can be accessed as:

```
channel_name = paramStruct.channel ;
start = str2num ( paramStruct.start_time ) ;
end = str2num ( paramStruct.stop_time ) ;
```

- All parameters obtained over the web are available are accessed as strings in Matlab

Java Socket used by Matlab

- Matlab uses Java sockets for communicating with the Servlet
- Data obtained over the web and results to be sent back to the browser are obtained by Matlab using this socket
- This socket uses Kerberos for secure communication with the Servlet

Sending Results to Browser

- Applications are responsible for generating HTML required to display results in the user’s browser
- Applications need only create the HTML in the form of a variable named *html*
- This string will be sent back to the user’s browser by the Java socket

Generating Images from Matlab plots

- **Images to be displayed in the browser should be in the JPEG format**
- **The Matlab *'print'* function is used to print figures to JPEG images**
- **Helper functions are provided for creating filenames, generating JPEG images and creating necessary HTML tags for displaying images**

Abstract
Presentation
Back to Agenda
Next Abstract

Example: Creating and Displaying Images

- **Following code illustrates the use of helper function for creating images:**

```
y = linspace(-2*pi,2*pi) ;
x = exp(y).*cos(y) ;
figure ;
handle = plot(x,y) ; axis tight ; grid ;
file_name = getFileName ;
makejpeg (file_name, handle) ;
html = addImage ( file_name ) ;
```

getFileName **: Returns a randomly generated filename**

makejpeg **: Prints the figure to JPEG format**

addImage **: Creates HTML <img> tags with appropriate file name and path to file**